UNITED STATES PATENT APPLICATION

of

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for

HIGH TEMPERATURE PAPER CONTAINING ARAMID COMPONENT

Attorney Docket No. 013400-197
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CROSS REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 60/409,230, filed on September 10, 2002, and is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to high temperature papers, and in particular to high temperature papers comprising an aramid component. Such high temperature papers can comprise a single layer or multiple layers.

Description of the Related Art

High temperature E-board is used in transformers and performs two functions. First, the E-board provides electrical insulation. This keeps the coils in the transformer from short circuiting. Secondly, the board provides mechanical strength. When there is a large passage of current through the transformer, there is force on the layers of the coil to move the board, which is glued to the coils. The glueing of the board to the coil keeps the various coils from telescoping. Each coil acts like a solenoid and tries to move. It is the E-board which prevents this telescoping.

Improving the mechanical strength of the E-board would aid in avoiding problems with telescoping coils. Having a reinforced E-board to strengthen the paper would help to provide the necessary mechanical strength. The paper, however, would have to be made in an efficient and effective manner.

There is also interest in increasing the temperature resistance of E-board for use in transformers so that a less expensive transformer could be designed. By reducing the diameters of the wires in a transformer, the coils would become smaller. Smaller coils require smaller cores and smaller metal containers. Smaller containers hold less oil, and this means that less copper for the wire, steel for the cores and oil for the insulation are needed. Because of the thinner wire, however, the transformer would have more electrical resistance and would run hotter. Thus, the E-board would have to exhibit enhanced thermal resistance before such a transformer would be practical.

A paper which exhibits such enhanced thermal resistance, as well as enhanced mechanical strength would allow the industry to design transformers which can recognize the economic benefits and performance benefits discussed above.

Accordingly, it is an object of the present invention to provide a paper structure which exhibits enhanced thermal resistance.

Yet another object of the present invention is to provide a paper structure which exhibits enhanced mechanical strength.

Still another object of the present invention is to provide a high temperature paper suitable for use in transformers.

These and other objects of the present invention will become apparent to the skilled artisan upon a review of the following description, and the claims appended hereto.

SUMMARY OF THE INVENTION

In accordance with the present invention, provided is a paper structure comprised of an aramid component. The paper structure comprises an aramid fiber and/or fibrid, a polymeric binder, such as polyvinyl alcohol, and cellulosic pulp fiber.

In a preferred embodiment, the paper structure is comprised of two outside layers and at least one inside layer. The two outside layers are preferably comprised of substantially cellulosic (wood) pulp fiber. The inside layer is comprised of cellulosic pulp fiber, the aramid fiber and/or fibrid and a polymeric binder. In a preferred embodiment, the structure comprises at least three inside layers, all comprised of cellulosic pulp fiber, the aramid component and a polymeric binder.

The resulting paper structure provides a paper quite useful as E-board in transformers due to its enhanced thermal resistance. Moreover, the aramid fiber also helps to reinforce the paper to avoid the problems in telescoping coils.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The paper structure of the present invention is quite useful as a high temperature E-board. The paper exhibits enhanced thermal resistance as well as good mechanical strength. The good thermal resistance would allow the use of the paper in a transformer with coils of smaller size as it would allow the coils to run hotter. Furthermore, the paper is also reinforced so that when glued to the coils, it would keep the various coils from telescoping. In actual use in a transformer, the paper is coated with an adhesive, such as an epoxy adhesive, and heat bonded to the wire coil surface. It is this bonding to the coils that permits the board to keep the various coils from telescoping. The mechanical strength of the paper structure of the present invention, including its aramid component in combination with the polymeric binder, permits the E-board to act efficiently and effectively while preventing the coils from telescoping.

The paper structure of the present invention comprises a polymeric binder, an aramid component which can be an aramid fiber, a fibrid, or a combination thereof, together with cellulosic pulp fiber.

The aramid fiber can be any commercially available polyaramid fiber, such as that under the trademark NOMEX®. Generally, the fiber is about 1/4 inch in length and has about a 2 denier. The fibrid is a small irregularly shaped piece of aramid polymer that is much larger in two dimensions than it is in the third dimension. It is like a microscopic corn flake in shape. The large dimensions are

on the order of 5 to 25 micrometers while the third and smaller dimension is about 0.01 to 1 micrometer.

In the paper structure, the amount of cellulosic wood pulp fiber generally ranges from 50 to 80 wt %, while the amount of aramid component generally ranges from about 5 to 25 wt %. The amount of polymeric binder, preferably polyvinyl alcohol, generally ranges from about 10 to 25 wt %. The aramid component, from 5 to 25 wt %, can be comprised of solely aramid fiber, aramid fibrid, or preferably a combination of the two. When a combination is used, it is preferred that about a 60/40 wt % ratio of fiber/fibrid is employed. When aramid fibrid is present, the amount of polymeric binder can be reduced as the fibrid can also function as binder for the web. For this reason, it is preferred that some aramid fibrid is present. It performs a dual role and can reduce the amount of aramid fiber and binder needed.

A minor amount of other synthetic fiber might also be present. Such synthetic fiber can be, for example, polyester or nylon fiber.

The paper structure of the present invention can comprise a single layer or multiple layers. When a single layer is employed, the paper structure contains the cellulosic pulp fiber, aramid component and polymeric binder as discussed above. Multiple layers of such combinations can also be employed, wherein the amounts of each component of a particular layer may change. Alternatively, a veiled structure can also be used. In such a veiled structure, the

two outside layers are comprised of substantially wood pulp fiber, preferably without any polymeric binder, while the inside layers, whether one or more, comprise the components of cellulosic wood pulp fiber, aramid component and polymeric binder. A minor amount of synthetic fiber, such as polyester or nylon fiber, can be present in the outside cellulosic pulp fiber layers.

When multiple layers are to be employed, it is preferred to make the paper structure using a cylinder machine, as is known in the art, with at least three different cylinders. Different stock compositions can be fed to each of the cylinders, which correspond to a particular layer of the paper structure.

In a preferred embodiment, the paper structure is comprised of five different layers. The two outside layers are comprised substantially of cellulosic, preferably wood, pulp fiber. The three internal layers are all comprised of cellulosic pulp fiber, aramid component and a polymeric binder. Optionally, the internal layers can be of different compositions. For example, they can contain different relative amounts of the cellulosic pulp fiber, aramid component and polymeric binder, since different stock compositions can be fed to the various corresponding cylinders to make the various layers. As well, it may be desired to have only one layer which contains the aramid component and the polymeric binder. The remaining layers would then be comprised primarily of cellulosic pulp fibers, or the relative amounts of fiber/fibrid within the aramid component can be changed.

In another embodiment, the paper structure comprises two outer layers comprised substantially of cellulosic pulp fiber, and the inner layer is comprised of the aramid component and polymeric binder. The presence of the aramid component and polymeric binder together is important, in at least one inner layer of the paper structure. The remaining layers may differ in composition, as long as the two outside layers do not contain the polymeric binder.

The preferred polymeric binder is polyvinyl alcohol, but other polymeric binders such as acrylics can also be used. It can be added in the form of a synthetic fiber or as a dry powder. If the binder is added as a fiber, it is important that the fiber has the proper chemical characteristics. Polyvinyl alcohol fiber is available with a wide range of water solubilization temperatures. The temperature at which the polymer becomes soluble depends on the properties of the polymer like the degree of polymerization, degree of hydrolysis, and crystallinity. This solubilization temperature can range from about 60°C to over 100°C. It is important to match this solubilization temperature to the paper making process. To be most effective the polyvinyl alcohol fiber should behave as a binder while it is in the fiber form. It should not be allowed to fully dissolve. The strongest binding occurs when the surface of the fiber just starts to dissolve. Then upon drying, the polyvinyl alcohol fiber will bond to all of the other fibers, both synthetic and natural, that it contacts.

This means that a polyvinyl alcohol fiber with a low solubilization temperature should be used with a low to medium basis weight paper (roughly 25 to 120 pounds per 3000 square feet) that is typically run at high machine speeds. Because of the higher machine speed and low sheet mass, evaporation will cool the paper. It will dry before it gets very hot. The maximum temperature that the paper will reach is likely to be less than 70°C.

With high basis weight papers (200 pounds per 3000 square feet and above) a polyvinyl alcohol fiber with a higher solubilization temperature can be used. These papers are typically run at slower machine speeds so that the sheet temperature is much higher.

When the powder form of the polyvinyl alcohol binder is used, the polymer should be fully hydrolyzed (99% or higher) and the polymer should be ground to a particle size of 100 mesh or smaller. The powder can be added to the wood fiber prior to refining or it can be added to the system after refining. It is important that the powdered polymer be allowed to swell after it is added to the paper making system. Swelling time depends on the water temperature. Cold water (0–14°C) requires a swelling period of about one hour. Warm water (40-50°C) will swell the particles in about 20 minutes. It is essential that the process water used with either polyvinyl alcohol fibers or powder not be over 60°C, as hot water will dissolve the polymer and most of the bonding characteristics will be lost.

It is advantageous to use a steam shower with the powder form of the polyvinyl alcohol binder. This shower should hit the paper prior to the dryer section. The steam shower is particularly useful with low basis weight papers. It will heat the sheet while it is still wet thus allowing the outside of the swollen polymer particles to begin to dissolve.

In preparing the "veiled" embodiment of the present invention, a cylinder machine, as is well known in the art, can be and is preferably employed. The cylinder machine allows for the creation of different layers using different stock compositions, as discussed above, thus allowing the paper structure to be tailored as needed within the present invention.

The process for making a veiled paper structure comprises feeding a stock composition comprised substantially of wood pulp fiber to the cylinders corresponding to the outer layers. Thus, the two outside layers of the resulting paper structure comprises substantially cellulosic, preferably wood, pulp fibers. A minor amount of synthetic fibers can be included in the stock compositions.

A cylinder corresponding to the inner layer is then fed with a stock solution comprised of cellulosic pulp fiber, the chosen aramid component, whether fiber, fibrid or a mixture thereof, and a polymeric binder. Thus, the inner layer of the paper structure is comprised of the cellulosic pulp fiber, aramid component and polymeric binder. The resulting paper structure is such that only the inner layer contains the polymeric binder, whereas the outside layers do not, and thus

potential sticking problems are avoided when the paper structure is dried, preferably on drier cans, and the polymeric binder is activated due to the high temperature. Upon activation of the polymeric binder, the binder acts to bind the aramid component together with the wood pulp fiber, and since it is on the inside layer it will not cause sticking problems.

The paper structure of the present invention, whether of a single layer or multiple layers, provides one with a paper quite useful as a high temperature paper for transformers. The paper exhibits enhanced thermal resistance, as well as excellent mechanical strength to perform all of the necessary functions of a transformer E-board.

While the invention has been described with preferred embodiments, it is to be understood that variations and modifications may be resorted to as will be apparent to those skilled in the art. Such variations and modifications are to be considered within the purview and the scope of the claims appended hereto.